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Effectiveness analysis of filters used with radon detectors under extreme environmental conditions for long-term exposures

V. Moreno*[,a], Ll. Font[a], C. Baixeras[a], J. Garcia-Orellana[a], J. Bach[b], C. Grossi[c,d], A. Vargas[c]

[a]*Unitat de Física de les Radiacions, Dpt. de Física, Ed. Cc, Universitat Autònoma de Barcelona, Bellaterra E-08193, Spain*
[b]*Unitat de Geodinàmica Externa i d'Hidrogeologia, Dpt. de Geologia, Ed. Cs, Universitat Autònoma de Barcelona, Bellaterra E-08193, Spain*
[c]*Institut de Tècniques Energètiques, Universitat Politècnica de Catalunya, Avda. Diagonal 647, Barcelona E-08028, Spain.*
[d]*Institut Català de Ciències del Clima, C/ Dr Trueta 203, Barcelona E-08005, Spain.*

Abstract

Active and passive radon detectors have been exposed with different filter configurations at the INTE radon chamber controlled conditions. Correction factors and delay times of the radon diffusion through each filter have been determined. Additionally, some of the studied filter/detector configurations have been used to measure radon in several workplaces and outdoor sites under real extreme environmental conditions. Analysis of these detectors showed partial degradation, so used filters seem not to be protective enough for long-term exposures.

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Keywords: Radon; workplace; long-term exposure; humidity; dusty environment.

1. Introduction

A previous study on long-term exposed nuclear track detectors showed that the use of plastic filters to protect radon detectors measuring in high humid environments should be considered (Moreno et al. 2013). In this paper the study is extended to other passive and some active radon detectors exposed in a reference radon chamber and then used under additional extreme environmental conditions (i.e. outdoors, dust and acidity) to analyse its effectiveness.

* Corresponding author. Tel.: +34-93-581-2935; fax: +35-93-581-2155.
E-mail address: Victoria.Moreno@uab.cat

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2. Methodology

Active and passive detectors have been exposed with different filter configurations (Table 1) at the INTE (Vargas et al. 2004) radon chamber controlled conditions (Table 2). Correction factors, f, and delay times of radon diffusion, τ_M (h), for each filter configuration have been determined (Moreno, 2012) using expressions (1) and (2).

$$f = \frac{C_{Rn\ reference}}{C_{Rn}} = \frac{\tau_M t}{\tau(t-\tau)} \quad (1)$$

where C_{Rn} is the radon concentration measured by the detector if we remove the filter immediately after the exposure is finished, $C_{Rn\ reference}$ is the reference radon concentration in the chamber, t is the exposure time (t >> τ) and τ is the effective delay time, obtained from (2), where τ_R is the radon mean lifetime.

$$\frac{1}{\tau} = \frac{1}{\tau_R} + \frac{1}{\tau_M} \quad (2)$$

Table 1. Characteristics of filters (commercial names and/or short descriptions) used with passive and active radon detectors.

Code	Filter commercial name and/or description	Detector
A	Without any filter	Actives and Passives
B	Tyvek (plastic bag of 115 ± 6 mm thickness)	Passives: Makrofol, CR-39, LR-115 and Electret
C	Treseses (plastic bag of 33 ± 2 mm thickness)	
D	Zipdar (plastic bag of 51 ± 2 mm thickness)	
E	Column of Drierite desiccant	RAD 7
F	Dust protection bag from Genitron (Tyvek).	AlphaGUARD
G	Black bag (not used for soil measurements).	Clipperton

Some of the studied filter/detector configurations have been used to measure radon in workplaces and outdoor sites under real extreme environmental conditions (i.e. humidity, dust and acidity) for 1-4 months (Table 3).

3. Results

Filter D and G present the highest delay times, τ_M (h), (Table 3) and correction factors, f, (Table 4). Additionally, correction factor is higher for detectors with large detection chambers, like LR-115 and Electrets HLT.

Table 2. Location and results of exposures at real extreme environmental conditions.

Location	Measured sites	t (month)	Configuration	Mean radon levels (Bq·m^{-3})
Underground mine	4 humid indoors (80-100% RH)	1	Makrofol + filters (A, B, C, D)	$[1 - 8]\cdot 10^3$
Spa	3 humid (50-90% RH) and hot (21-29ºC) rooms	4		89 – 222
Peníscola marsh	5 humid outdoor at 1 m from soil	3		36 – 43
Dicalcium phosphate (DP) production plant	4 dusty indoors, 1 outdoor with acid	3.7		12 – 220

Table 3. Delay time of radon diffusion, τ_M (h), for each configuration (detector + filter).

Detector	B	C	D	E	F	G
Makrofol	0.7 ± 0.5	3.1 ± 0.6	5.0 ± 0.6	-	-	-
Electret SLT	0.0 ± 0.5	4.6 ± 0.6	5.0 ± 1.5	-	-	-
Electret HLT	0.0 ± 0.5	13 ± 1	12 ± 1	-	-	-
Electret HLT -^{220}Rn filter	3.6 ± 2.1	6.7 ± 3.1	10 ± 2	-	-	-
Actives	-	-	-	3.0 ± 0.2	0.1 ± 0.1	8.7 ± 0.5

Mean radon levels obtained with passive detectors in the underground mine are higher than 600 Bq m^{-3} (Table 2), the Spanish action level in workplaces (IS-33, 2012), while in the spa and the DP production plant radon levels are lower, but punctual and continuous measurements by active detectors showed a wide range of radon levels, up to 1.7 ± 0.1 kBq m^{-3} in the spa and up to 760 ± 98 Bq m^{-3} in galleries where the DP is transported before treatment. Detectors exposed in locations with the most extreme environmental conditions were partially degraded.

Table 4. Exposure conditions in the INTE radon chamber and correction factor, f, obtained for each configuration exposed.

EXPO	Exposure conditions		Configuration exposed (detector + filter code)					
	Parameter	Value	Detector	A	B	C	D	E, F, G
1	$C_{Rn\ ref}$ (kBq·m^{-3})	8.5 ± 1.2	Makrofol	1.12 ± 0.08	1.11 ± 0.08	1.12 ± 0.08	1.21 ± 0.09	
	Temp. (ºC)	20 ± 1	Elect. SLT	0.92 ± 0.06	0.95 ± 0.07	1.10 ± 0.08	1.10 ± 0.08	
	RH (%)	45 ± 1	Elect. HLT	1.00 ± 0.07	1.02 ± 0.07	1.33 ± 0.09	1.28 ± 0.09	
	t (h)	74.0 ± 0.2	Elect. HLT -^{220}Rn filter	1.10 ± 0.08	0.99 ± 0.07	1.30 ± 0.09	1.29 ± 0.09	
2	$C_{Rn\ ref}$ (kBq·m^{-3})	17.0 ± 2.4	Makrofol	0.97 ± 0.07	0.96 ± 0.07	1.09 ± 0.08	1.10 ± 0.08	
	Temp. (ºC)	20 ± 1	LR115	0.99 ± 0.07	1.45 ± 0.17	1.46 ± 0.16	2.07 ± 0.35	
	RH (%)	45 ± 1	Elect. SLT	0.95 ± 0.07	1.00 ± 0.07	1.08 ± 0.08	1.06 ± 0.07	
	t (h)	67.0 ± 0.2	Elect. HLT - ^{220}Rn filter	1.07 ± 0.08	1.11 ± 0.08	1.08 ± 0.08	1.29 ± 0.09	
			ATMOS 12DPX	0.99 ± 0.05				
			AlphaGUARD	1.00 ± 0.05				
			RAD 7					1.08 ± 0.08
3	$C_{Rn\ ref}$ (kBq·m^{-3})	20.0 ± 2.8	Makrofol	1.06 ± 0.07	1.03 ± 0.07	1.10 ± 0.08	1.02 ± 0.07	
	Temp. (ºC)	20 ± 1	Elect. – SLT	0.97 ± 0.07	0.99 ± 0.07	1.17 ± 0.08	1.24 ± 0.09	
	RH (%)	45 ± 1	AlphaGUARD	1.01 ± 0.06				
	t (h)	50.0 ± 0.2	Clipperton					1.30 ± 0.09
4	$C_{Rn\ ref}$ (kBq·m^{-3})	20.0 ± 2.8	Makrofol	0.89 ± 0.06	0.96 ± 0.07	0.99 ± 0.07	0.97 ± 0.07	
	Temp. (ºC)	20 ± 1	CR-39	1.09 ± 0.08	1.06 ± 0.07	1.12 ± 0.08	1.08 ± 0.08	
	RH (%)	85 ± 1	Elect. SLT	1.03 ± 0.07	0.99 ± 0.07	1.31 ± 0.09	1.05 ± 0.07	
	t (h)	50.0 ± 0.2	Elect. HLT - ^{220}Rn filter	1.11 ± 0.08	1.08 ± 0.08	1.34 ± 0.10	1.51 ± 0.11	
			ATMOS 12DPX	1.01 ± 0.06				
			AlphaGUARD					1.00 ± 0.05
			Clipperton					1.29 ± 0.09
5	$C_{Rn\ ref}$ (kBq·m^{-3})	20.0 ± 2.8	Makrofol	1.00 ± 0.07	1.11 ± 0.08	1.22 ± 0.09	1.17 ± 0.08	
	Temp. (ºC)	30 ± 1	LR115	1.01 ± 0.07	1.02 ± 0.07	1.11 ± 0.08	1.59 ± 0.21	
	RH (%)	85 ± 1	CR-39	1.00 ± 0.07	1.01 ± 0.07	1.02 ± 0.07	1.01 ± 0.07	
	t (h)	49.5 ± 0.2	Elect. SLT	1.00 ± 0.07	1.21 ± 0.09	1.12 ± 0.08	1.02 ± 0.07	
			Elect. HLT - ^{220}Rn filter	1.16 ± 0.08	1.11 ± 0.08	1.35 ± 0.10	1.44 ± 0.11	
			ATMOS 12DPX	1.01 ± 0.06				
			AlphaGUARD					1.08 ± 0.08
			Clipperton					1.04 ± 0.11

4. Conclusions

For short exposures in controlled conditions humidity effect is not significant and the polyethylene bag that less influences detector response is the Tyvek bag. However passive detectors exposed in locations with the most extreme environmental conditions are partially degraded. Filters used do not protect enough for long-term exposures.

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